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Ocean Coupling to Topographically-Enhanced Atmospheric Flow

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LONG-TERM GOALS

The goal of this project is to understand and predict oceanic and atmospheric processes in coastal areas where winds are topographically steered and strengthened.

OBJECTIVES

The proposed work aims to probe details of the interaction of mountainous island terrain with synoptic and intra-seasonal disturbances, and the associated ocean response and feedback. The research questions include:

- How do intra-seasonal and synoptic disturbances combine to generate spatial/temporal variability of the ocean and atmosphere on small time and space (e.g., operational) scales?

- How do terrain effects influence local precipitation and wind patterns during atmospheric episodes?

- How do warm wake waters surrounding islands impact the atmosphere during synoptic and intra-seasonal events? What is the evolution of atmospheric and oceanic boundary layers over the course of atmospheric passages, and what role do wind orientation and terrain play?

APPROACH

To accomplish these objectives we employ high-resolution (~1-3 km) two-way coupled ocean/atmosphere modeling to predict, interpret and improve the simulated boundary layer properties. The studies mine the rich datasets of observational programs including satellite, moored and underway observations to form a more complete picture of circulation characteristics in the ocean and atmosphere in complex coastal mountainous regions. The project is a close collaboration with NRL partners on the modeling side (including James Doyle, Paul May and Sue Chen) and field team participants (including Arnold Gordon of Lamont-Doherty Earth Observatory, Janet Sprintall of Scripps, Craig Lee of University of Washington and Laura David of University of the Philippines).

Report Documentation Page

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WORK COMPLETED

We conducted an extensive examination of wind-driven aspects of a pronounced flow reversal in Mindoro Strait, using high-resolution ocean and atmosphere simulations combined with a suite of observations that include moorings, CTD casts, and underway meteorological and oceanographic shipboard sampling. This multi-institutional collaboration resulted in a paper [see 1.) below] and presentation:

<u>Atmospheric and oceanic processes in the vicinity of an island strait</u>, Julie Pullen, A. Gordon, J. Sprintall, C. Lee, M. Alford, J. Doyle, and P. May, 9th Conference on Coastal Atmospheric and Oceanic Prediction and Processes & 17th Conference on Air Sea Interaction, September 27-29, 2010, Annapolis, MD

Additional studies of two-way coupled (COAMPS®[1]) simulations using 1 and 3 km oceanic model resolutions and 3 and 9 km atmospheric model resolutions produced a paper [see 2.) below] detailing the conditions during two research cruises. That research also documented a wind-driven upwelling event in Verde Island Passage and explored the implications for biological productivity in the area. ([1] COAMPS® and COAMPS-OS® are registered trademarks of the Naval Research Laboratory.)

RESULTS

1.) A reversal of the mean flow through the Philippines' Mindoro Strait occurred in early February 2008. The flow was southward through the strait during late January and northward during most of February. The flow reversal coincided with the period between two intensive observing cruises (IOP08-1 and IOP08-2) sponsored by Office of Naval Research (ONR) as part of the Philippine Straits Experiment (PhilEx). High-resolution air/sea modeling simulations captured the flow reversal and agreed with measured currents from two moorings in the vicinity of Mindoro Strait (Figure 1).

A short (24-27 January) easterly monsoon surge and a longer (9-16 February) northerly surge were represented in the model as well as in QuikSCAT and underway wind data taken during IOP08-2 (Figure 2). In the Panay jet, (cross in Figure 2b) easterly surge mean winds of 12.7 m s^{-1} and standard deviation of 1.3 m s^{-1} were produced in the model. The event attained maximum winds in the Panay jet of 14.5 m s^{-1} in the model. This particular wind surge lasted ~3 days, as determined by model winds exceeding the model wintertime mean (~11 m s^{-1}) by one standard deviation (~3 m s^{-1}), with diminished intensity intervals lasting less than 24 hours. About 12 days later the winds again intensified as part of a cold surge originating from the Asian mainland, with the winds this time displaying a more northerly orientation. The prolonged northerly surge was longer in duration and stronger in intensity than the earlier easterly surge. The downwind extent of the Panay wind jet ran parallel to the island of Palawan in both the model and satellite fields – thereby illustrating the northerly orientation of this particular event (Figure 2c & d). The northerly surge lasted ~7 days with maximum wind strength in the Panay jet of 17.1m s^{-1}. The mean wind speed in that location (marked by a cross in Figure 2d) over the ~7-day event was 12.9 m s^{-1}, with standard deviation of 1.8 m s^{-1}. Except for its prolonged duration, the statistical characteristics of this event are similar to the northerly surge identified and analyzed in Pullen et al. (2008).

Mesoscale oceanic dipole eddies off Mindoro and Luzon (Pullen et al., 2008) were formed/enhanced and subsequently detached by these wind events. The cyclonic eddy associated with the easterly surge was opportunistically sampled during the IOP08- 1 cruise and the modeled eddy characteristics were

verified using in situ shipboard data. The presence of the cyclonic eddy near Mindoro Strait favored a geostrophic flow southward through the strait. This dominant flow was interrupted by a strong and sustained wind-driven (northerly surge) flow reversal in early February when the cyclonic eddy was absent. Enhanced upper ocean stratification in winter 2008 due to anomalously high precipitation served to isolate the near-surface circulation in the observations more so than was attained in the model results. The model configuration did not account for river run-off nor accurately predict local rainfall. Future simulations will include river discharge and improved microphysical parameterizations.

2.) A separate series of two-way coupled atmosphere (9 & 3 km)/ocean (3 & 1 km) simulations of the Philippines show the regional and local nature of atmospheric patterns and ocean response during the January- February 2008 (IOP08) and February-March 2009 (IOP09) field experiments. Winds were stronger and more variable during IOP08 because the time period covered was near the peak of the northeast monsoon season. The modeled upper ocean flow associated with the Philippine straits during IOP08 has a large (>1 m s^{-1}) westward mean flow through the Suriago Strait and highly variable flow through the Mindoro Strait. Prominent eddies in the Bohol Sea and Cuyo East Pass observed during the field experiment are also seen in model simulations. A 1-km resolution nested simulation of the Verde Island Passage finds local wind-driven upwelling with enhanced biological productivity that is confirmed by satellite observations of chlorophyll concentration and shipboard sea surface temperature measurements (Figure 3).

IMPACT/APPLICATIONS

Insight into processes in coastal areas subject to topographically-enhanced winds are translatable to other regions of interest to the Navy.

TRANSITIONS

none

RELATED PROJECTS

This work is related to NRL-Monterey 6.1 projects within PE 0601153N that include studies of air-ocean coupling, boundary layer studies, and topographic flows and 6.2 projects within PE 0602435N that focus on the development of the atmospheric components of COAMPS. This work also draws on efforts conducted within the ONR PhilEx DRI.

REFERENCES

Pullen, J., J. D. Doyle, P. May, C. Chavanne, P. Flament and R. Arnone, "Monsoon surges trigger oceanic eddy formation and propagation in the lee of the Philippine Islands," Geophysical Research Letters, 35, L07604, doi:10.1029/2007GL033109, 2008

PUBLICATIONS

1.) Pullen, J., A. Gordon, J. Sprintall, C. Lee, M. Alford, J. Doyle, and P. May: Winds, Eddies, and Flow through Straits, [submitted, refereed].

2.) May, P., J. Doyle, J. Pullen, and L. David: Two-Way Coupled Atmosphere-Ocean Modeling of the PhilEx Intensive Observing Periods, [submitted, refereed].

3.) Rypina, Irina I., Lawrence J. Pratt, Julie Pullen, Julia Levin, Arnold L. Gordon, 2010: Chaotic Advection in an Archipelago. *J. Phys. Oceanogr.*, 40, 1988–2006.
doi: 10.1175/2010JPO4336.1

PATENTS

none

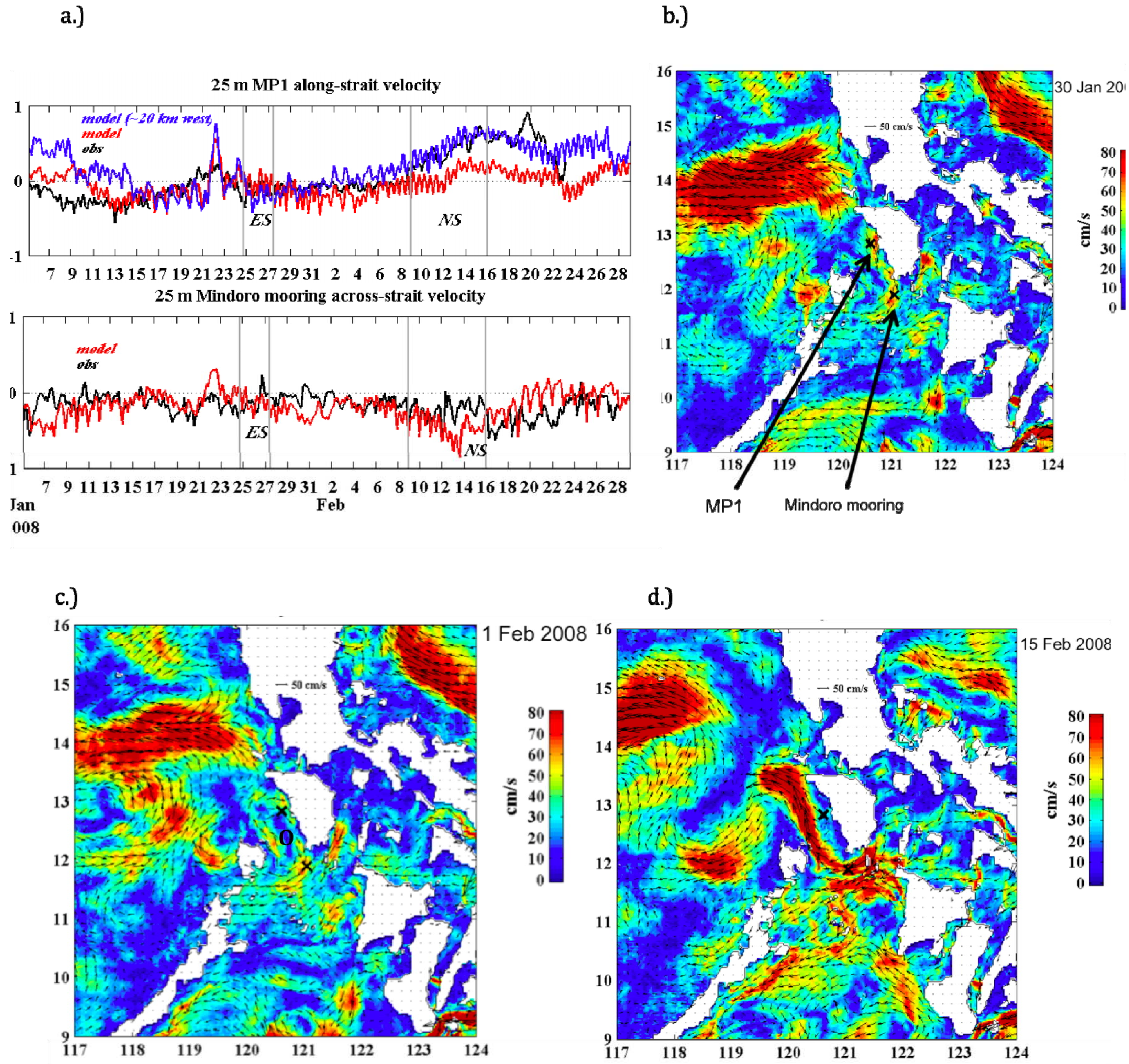

Figure 1: (a.) Measured and 3-km resolution modeled 25 m currents at two moorings: MP1 and the Mindoro mooring, whose locations are shown with crosses. Other panels show snapshots of the model-produced 25 m current field on (b.) 30 January, (c.) 1 February, and (d.) 15 February 2008. Currents are rotated -45 degrees to create along and across-strait velocities. The "O" in panel c.) denotes the core of the small anticyclonic eddy within Mindoro Strait that often occurs, especially during flow transition times. Also present (e.g., panel c.)) is the eddy dipole between 12N and 15N in the South China Sea.

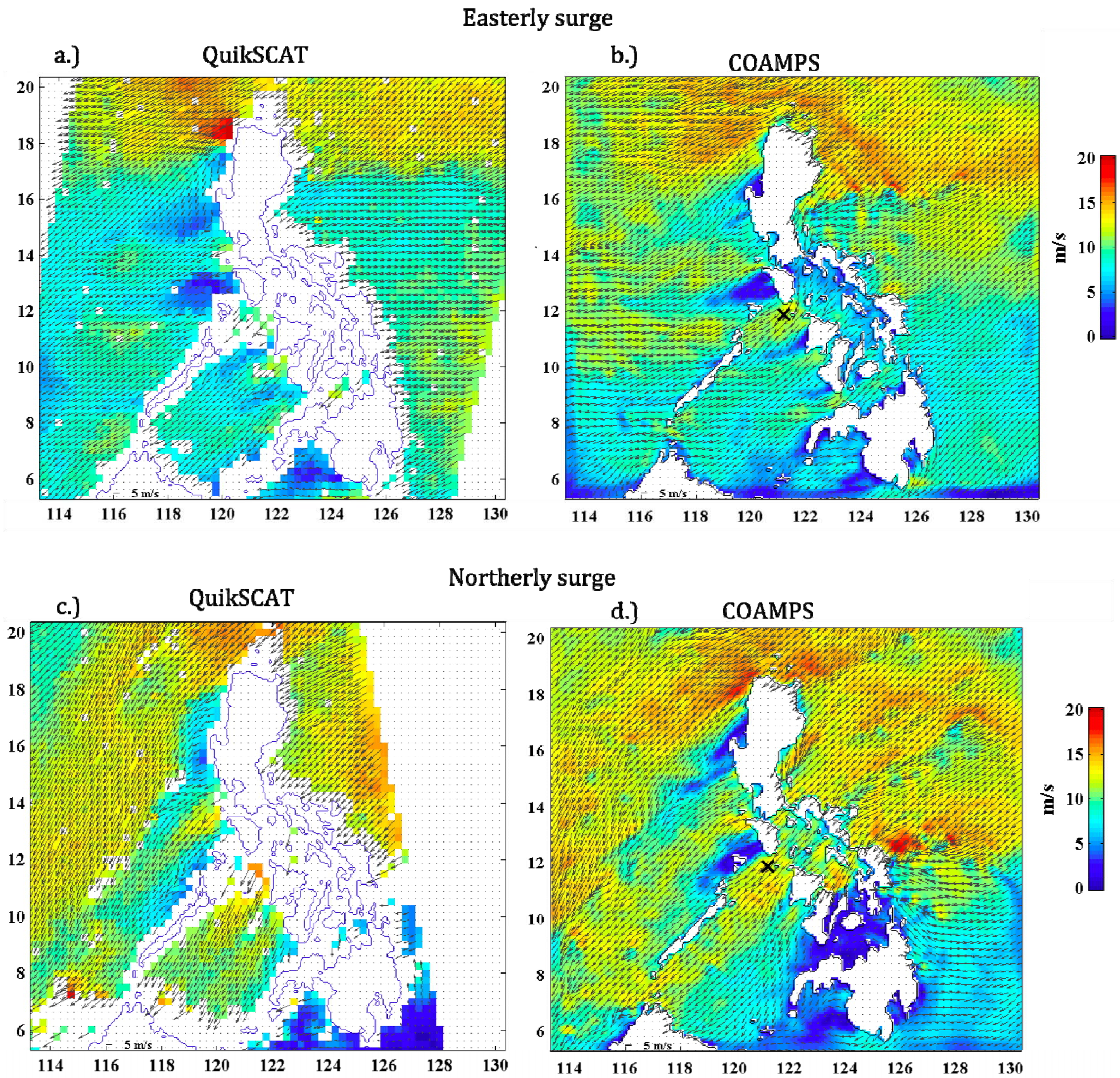

Figure 2: Near-surface winds (m s^{-1}) from (left) QuikSCAT satellite (approximately 25 km resolution) and (right) COAMPS (9 km resolution) during two different monsoon surges in winter 2008. The top shows winds from an easterly surge on 9 UTC 25 January 2008, while the bottom shows winds during a northerly surge that occurred on 21 UTC 15 February 2008. The cross is located in the Panay wind jet.

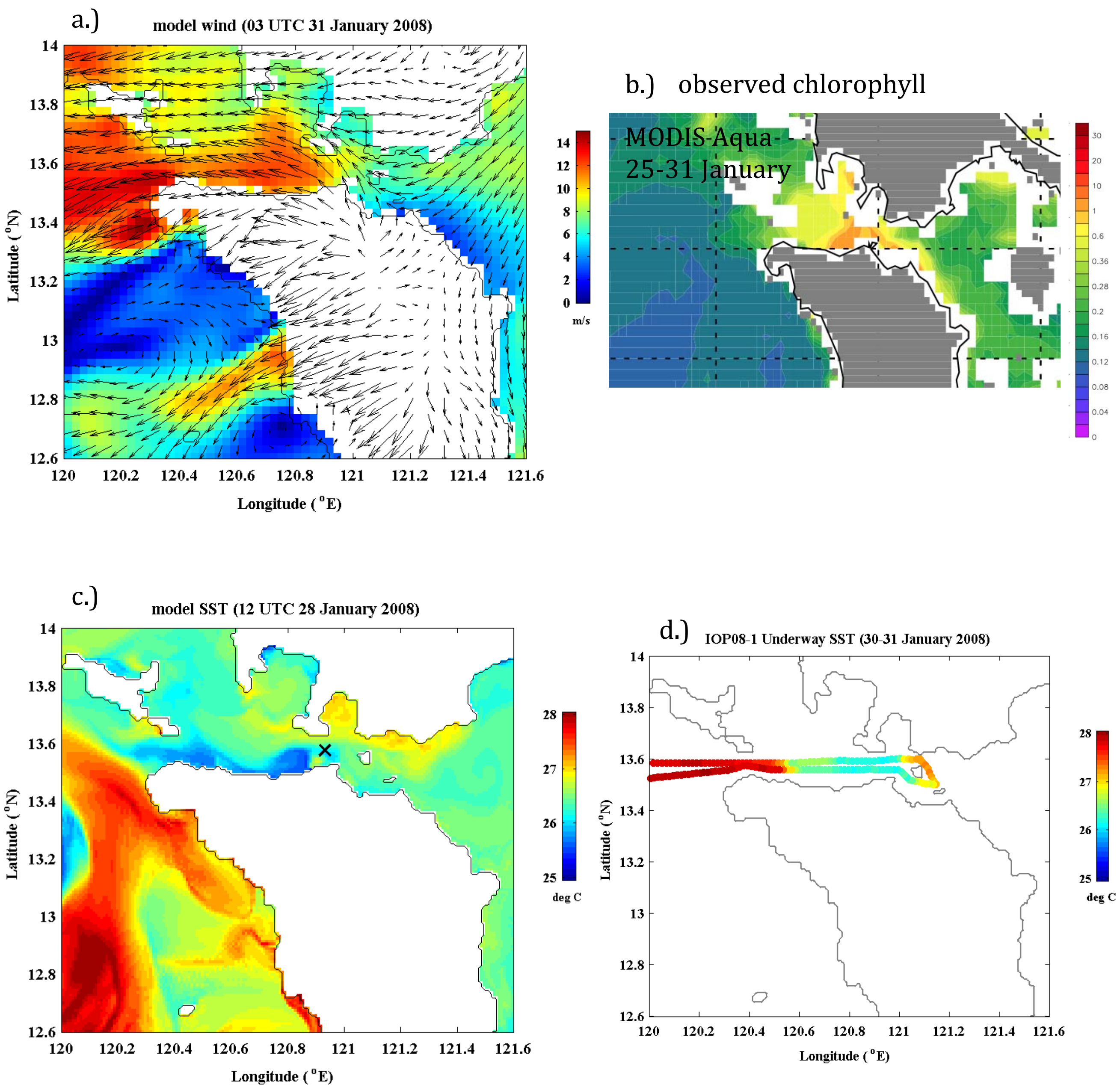

Figure 3: a.) 3 km model winds on 31 January 2008
b.) 25-31 January 2008 MODIS Aqua composite chlorophyll.
c.)1 km model SST on 12 UTC 28 January 2008.
d.) Underway SST from IOP08-1 from 30-31 January 2008.